Codes and Standards Enhancement Initiative
For PY2004: Title 20 Standards Development

Analysis of Standards Options
For
Very Large Air-Cooled Unitary Air Conditioners

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1. Introduction

The Pacific Gas and Electric Company (PG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. The objective of this project is to develop CASE Reports that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards. This CASE report covers standards and options for very large air-cooled unitary air conditioners.

2. Product Description

Air-cooled unitary air conditioners are assemblies that contain evaporators, condensers, compressors, air distribution fans, and controls in a single unit (often called a *single-package* unit) or two units (often called a *split* unit). They are commonly located on the roof of low-rise buildings (hence the common name "rooftop air conditioners"). Rooftop units are lower cost than chillers, and hence they are frequently used for low-rise buildings (air circulation costs become prohibitive for high rises and hence chillers are more frequently employed in high rises). In this CASE study we focus only on air-cooled – systems that reject heat to the air. We do not discuss the much less popular water- and ground-source systems here. [1]

Most air-cooled unitary commercial air conditioners range from 3 to 20 tons in cooling capacity (36,000-240,000 Btu/hr cooling capacity) and are regulated by existing federal efficiency standards. However, systems of 20 tons and up are not covered. Heat pumps are not uncommon in systems less than 20 tons in capacity, but are very rare in systems of 20 tons and over.

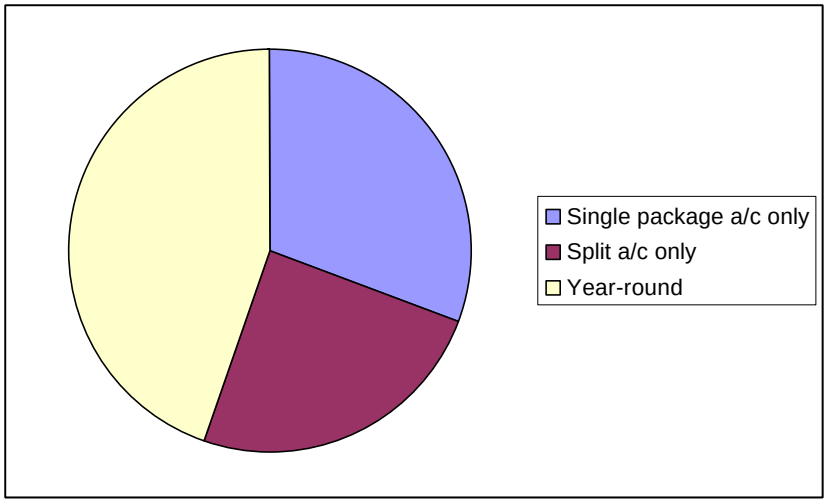
Very large air-cooled unitary air conditioners tend to be of two varieties. Smaller systems (e.g. 20, 25, 30 tons) are commonly built and held in stock for subsequent sales. Larger systems (typically over 30 tons) are often custom ordered and built, based on a variety of standard designs and options. These larger units are generally not held in stock. Systems can commonly be as large as 60 tons or more in cooling capacity, although the upper limit varies from manufacturer to manufacturer. We use 63 tons for the upper-size limit for these products since that is the end of a size category for this equipment in ASHRAE 90.1.

Very large air-cooled unitary air conditioners come as cooling-only models, and as "year-round" units, which contain a heating source as well. The heating source can be electric resistance or can be connected with a gas burner. These latter units are commonly called "Gas-Paks". In addition, a few heat pumps may be produced in this size range, but heat pumps this large are very rare. The distribution of 2002 national shipments of very large air-cooled unitary air conditioners by system type is estimated in Figure 1. We provide

[1] Water- and ground-source systems reject heat to water and the ground respectively. Efficiencies and costs are very different for these systems. Furthermore, these water- and ground-source units generally have smaller cooling capacities than the very large air-cooled units discussed in this CASE study.

national data because very little California-specific data is available that differentiates equipment over 20 tons of cooling capacity.

Figure 1. Very Large Air-Cooled Unitary Air Conditioner Shipments, Total Cooling Capacity Shipped as a Function of System Type.



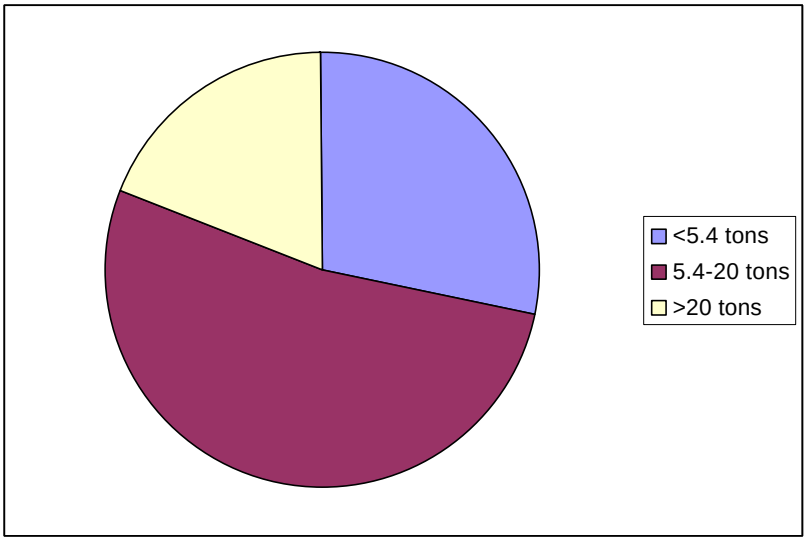
Source: ACEEE estimate based on data in U.S. Census 2003.

3. Market Status

3.1. Market penetration

A 1999 study by PG&E estimated that 61% of commercial facilities with cooling use unitary units (PG&E 1999). Data on penetration by equipment size are available, including estimates derived from national sales data and a study on the California market. Figure 2 indicates the approximate market share of equipment by size, based on national shipment data from 2002.

Figure 2. Commercial Air-Source Unitary Air-Conditioner U.S. Shipments, Total Cooling Capacity Shipped as a Function of Unit Capacity.

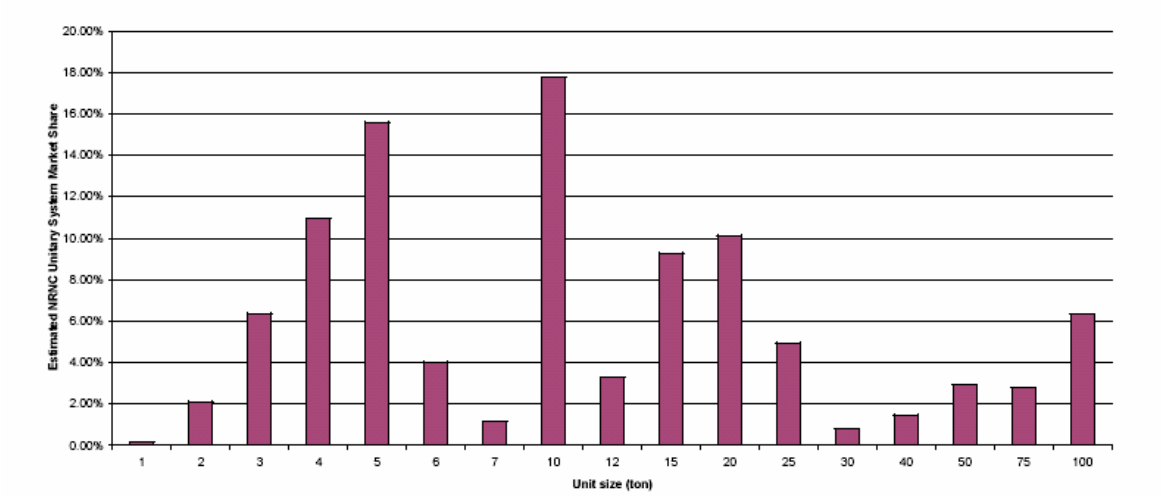


Source: ACEEE estimate based on data in U.S. Census 2003. These figures assume that only 10% of total shipments below 5.4 tons are for the commercial sector.

Based on the 2002 sales estimate for California (discussed below) and a 15 year equipment life (discussed in section 5.2), the total California stock of very large air-cooled unitary air conditioners is approximately 54,000 units.

More detailed data on the distribution of equipment in California by unit size is provided by a 2001 study prepared for California's Public Interest Energy Research program (Jacobs 2001). This data is summarized in Figure 3.

Figure 3. Distribution of Air-Cooled Unitary Air-Conditioner System Size by Installed Capacity.



Source: Jacobs 2001.

3.2. Sales Volume

The U.S. Census Bureau Current Industrial Reports tracks sales by year. Their estimates of sales at a national level, by year are summarized in Table 1. This table includes air-cooled single-package, single-package year-round (with heating units), and split systems (we do not include heat pumps as there are extremely few sold in this size range). The Census Bureau includes models with 185,000-249,999 Btu/hr cooling capacity as a size category. We interpolate from these data to estimate shipments of units of 240,000 Btu/hr and up.

Table 1. Census Bureau Estimates of Air-Cooled Unitary Air Conditioner Shipments, 240,000 Btu/hour and Larger

Year	2001	2002
Shipments	39,974	32,882

Source: U.S. Census 2003.

ARI also keeps sales data for this equipment. While the data are not published, ARI staff report that their estimates are somewhat lower than the Census estimates (Amrane 2003).

California accounted for about 11% of U.S. non-residential construction activity in 2001 (U.S. Census Bureau 2002). Assuming California also accounts for 11% of very large commercial air conditioner sales, we estimate annual sales in California of 3,600 units per year, based on the Census Bureau sales data.

3.3. Market penetration of high efficiency options

A study by ICF Consulting for PG&E estimates that 25% of air-cooled unitary commercial air conditioners being sold are high efficiency, which this study defines as EER 10.1 for 20 ton units. However, this study does not cover equipment over 20 tons (ICF Consulting 2000).

Industry experts we consulted with estimate that 17% of very large unitary air conditioning systems sold nationwide in 2002 meet CEE tier 2 (EER of 10 or more), an additional 23% meet the ASHRAE 90.1-1999 level (EER of 9.5 for units without heat pumps or gas-pak heating units, 9.3 for units with heat pumps or gas-paks) and the remainder are less efficient.

While only 17-25% of equipment is high-efficiency, due to the impacts of Title 24, a significant proportion of equipment sold in California is medium efficiency. Under Title 24, equipment of 20 tons or more is required to have an EER meeting ASHRAE 90.1-1999. While implementation of Title 24 is not perfect, particularly for replacement systems in existing buildings, it is likely that a substantial majority of equipment sold in California meets the Title 24 standard.

We also looked at availability of equipment meeting CEE tier 2. Table 3 summarizes available models meeting CEE tier 2 as found in a search of company web sites.

Table 3. Very Large Air-Source Unitary Air Conditioning Units (20 tons or more) Meeting CEE Tier 1 (EER 10 or more)

Manufacturer	Units of 20-30 tons	Units Over 30 tons
Lennox	20 ton unit has EER of 11.0	Don't produce any models in this size range
Trane	22 and 25 ton units have EER of 10.6 and 10.4 respectively	SCRF/SIRF series of units from 20-60 tons has EERs of 9.9-11.3 (no further details provided)
Carrier	20 and 25 ton units have EER of 11.2 and 10.4 respectively	No efficiency information on web
Aon	20-25 ton units vary from 10.5-11.0 EER (no further details provided)	RK series of units from 26-60 tons has an EER of 9.8-10.5 (no further details provided) RF series of units from 40-130 tons has an EER of 9.7-11.9 (no further details provided)
McQuay	Efficiency information not on their web site	

York	Y series 25 ton unit has an EER of 10; DJ series from 15-24 tons has EERs of 10.3-11.8 (no further details provided)	Produce 40 and 50 ton units but do not meet EER 10.
Rheem	Website mentions 25 ton unit but provides no details.	Don't produce any models in this size range

Source: Review of company websites, Oct. 2003.

4. Savings Potential

4.1. Baseline energy use

Industry experts estimate that the sales weighted average capacity for units in the 20-63 ton size range is 368,000 Btu/hour, or 30.67 tons. ASHRAE, in developing the 1999 edition of 90.1, estimated that air-cooled unitary commercial air conditioners are used for an average of 1593 full-load hours nationally. The analysis included two California cities – Fresno and Los Angeles – both of which had average full-load hours above the national average. On the other hand, northern California is cooler, so using the national average is a reasonable approximation for California. For our baseline unit, we assume a unit just meeting Title 24, with an average EER of 9.4 (midway between the two product categories). Some units now being sold exceed this level, but it is also likely that Title 24 is not fully enforced at the local level and thus some units being installed do not meet the Title 24 requirements. Using these estimates, the average baseline peak demand is:

368,000 Btu/hr / 9.4 EER = 39 kW load at 95 degrees F

On the one hand, peak demand in California is often at temperatures above 95 degrees F. On the other hand, many air conditioners are oversized so that even under peak conditions some cycling may occur. We estimate that these factors roughly cancel each other out and therefore that 39 kW is a reasonable estimate of peak demand for an average baseline unit.

Average annual kWh can be estimated by multiplying peak load by estimated full-load operating hours:

39 kW * 1593 hours = 62,000 kWh/year.

4.2. Proposed test method

Very large air-cooled unitary commercial air conditioners are generally rated using ARI standard 340/360-2000. This standard is referenced in Title 24 and we recommend also using this standard for Title 20.

4.3. Efficiency measures

Efficiency of very large air-cooled unitary commercial air conditioners can be increased with an array of standard options including high efficiency compressors, high efficiency fan motors, and increased evaporator and condenser area. Variable speed is also an

option for saving energy (e.g., as measured by IPLV) but generally not for saving peak (e.g., as measured by EER).

4.4. Standards Options

The main standards option is to adopt CEE tier 2, which calls for an EER of 10 or more. This level has been extensively promoted for several years through utility and public benefit programs around the country associated with CEE, and has significant availability and market share. Of the five manufacturers providing efficiency information on the web in this size range (see Table 3), all have at least some models that meet this level.

A level of EER 10.5 is also feasible since there are several units on the market meeting these levels (e.g. five manufacturers listed in Table 3 have some equipment at this level). Price data is also available.

We recommend that standards be applied to equipment from 240,000-760,000 Btu/hour (20-63 tons) (the 760,000 figure is the upper bound for this equipment used by ASHRAE 90.1). For this equipment, standards should apply only to air-conditioners and not heat pumps as there are too few air-source heat pumps sold in this size range to usefully regulate.

4.5. Energy Savings

Total savings and peak demand savings represent the hypothetical statewide impact if all very large commercial packaged air conditioning units in the California stock were replaced with units at the proposed new standard level, instead of at Title 24 efficiencies. These savings estimates are summarized in Table 4.

Table 4: Estimated Savings for Proposed Standards Options

Standard Option	Per Unit Savings		Projected Savings (million kWh/year)	Projected Peak Demand Savings (MW)
	kW	KWh/year		
EER 10	2.35	3742	203	127
EER 10.5	4.10	6533	354	222

Note: Census Bureau 2002 shipment data used to calculate these estimates. These projected savings will be achieved after the equipment stock turns over – about 15 years after the standard takes effect.

5. Economic Analysis

5.1. Incremental cost

Several data sources are available that estimate the incremental cost of air-cooled unitary air conditioners of 15 tons and larger. Only a few of these sources cover units above 20

tons, so to broaden the number of data points, we include 15 and 20 ton units in the discussion.

A total of four data sources are available: (1) an estimate by PNNL for DOE in 2000, that in turn was based on data collected by ASHRAE in the early 1990's; (2) a new July 2003 estimate by Tiax and LBNL for DOE; (3) a 1998 study for Northeast Energy Efficiency Partnerships by Northeast Utilities; and (4) a 2000 study by ICF Consulting for PG&E. Estimates from these studies are summarized in Table 5.

Table 5. Incremental Cost Per Ton for High-Efficiency Very Large Air-Cooled Unitary Air Conditioners

Study	Unit Size (tons)	Basecase EER	High-Efficiency EER	Incremental Cost per Ton	Incremental Cost per Ton per EER Point
PNNL in DOE 2000	15 	8.5 9.7 10.2	9.7 10.2 10.4	$54.40 $18.13 $13.60	$45 $36 $68
LBNL 2003	15 	9.5 10.1 	10.1 10.5 	$16.60 $13.93 	$28 $35
NU 1998	>20	9	10.7	$49	$29
ICF 2000	20 (a/c) 20 (hp)	8.9 8.5	10.1 10.2	22% 14%	$82* $37*

* Assumed $450/ton cost for basecase unit in order to calculate these figures.

When a new standard is implemented, sales of high-efficiency equipment will be high since all equipment must be efficient. With high sales and routine stocking, equipment prices are generally much less than if efficient equipment is just a limited quantity niche product. The LBNL estimates capture these economies of scale from a new standard. The NU estimates are strikingly similar. The LBL figures are also useful in that they include EER 10 and 10.5 equipment and indicate a fairly constant slope at this point in the price/efficiency curve. The ICF figures are based on the cost of niche products and can be expected to decline as sales increase. The PNNL estimates are based on a very conservative estimate of likely costs made in 1993 (see Nadel 2000 for a detailed criticism of these estimates). Thus, for our analysis we use the most recent cost estimates from LBL and Tiax -- $28/EER point per ton to go to EER 10, and $35/EER point per ton to go from EER 10 to EER 10.5. These are reasonable estimates of the incremental cost of more efficient equipment assuming a standard. As a sensitivity case, we also analyzed a figure double these amounts and more in line with the old PNNL and ICF figures.

5.2. Design life

The ASHRAE Handbook of Applications estimates that air-cooled unitary commercial air conditioners have an average life of 15 years (ASHRAE 1999).

5.3. Life cycle cost

Using the assumptions outlined above, we calculated the following life cycle cost for an average very large unitary air conditioner under each of the proposed standards scenarios.

Table 6: Impacts of Proposed Standards Options for Very Large Commercial Air-Cooled Unitary Air Conditioners

Proposed Standard	Design Life (years)	Annual Energy Savings (kWh)	PV of Energy Savings ($) [r = 3%]	Incremental Cost, Retail ($)	NPV to Consumer ($)
EER 10	15	3742	$3674	$504	$3170
EER 10.5	15	6533	$6416	$924	$5492

Note: Figures are for a 30 ton unit with a base efficiency of 9.4 EER. Estimated incremental cost of $30/ton per EER point of improvement. Financial savings based on CEC 2001 estimates of the present value of energy costs for medium commercial customers (Martin and Holland 2001). These costs are for average load shapes; savings for equipment with high peak use (such as air conditioners) will be higher.

As a sensitivity case, we also doubled the incremental costs (as discussed in section 5.1). Under this case, and with all other assumptions unchanged, the NPV to users is $2666 in savings for EER 10 and $4568 in savings for EER 10.5.

6. Acceptance Issues

6.1. Infrastructure Issues

Much of this equipment is custom-ordered to a user selected efficiency level, so meeting this standard will generally not be difficult for the larger units. For 20, 25 and 30 ton units, some manufacturers now produce these units and others do not. Time should be allowed (we would suggest about two years) for manufacturers to develop new complying products. Furthermore, a large proportion of this equipment is sold during the summer and fall because that is when most old units fail and many new construction projects are completed. Thus, manufacturers prefer that a standard take effect around October 1 or after rather than in the middle of the busy season. Given these considerations, if this standard takes effect in 2006, we recommend an effective date of October 1, 2006.

6.2. Existing Standards

Under the federal Energy Policy Act of 1992, commercial unitary air-cooled air conditioners up to (but not including) 20 tons are covered by federal standards. This standard is now 8.9 for equipment of 5-11 tons and 8.5 for equipment from 12-20 tons. This standard is now being revised by DOE.

ASHRAE standard 90.1-1999 includes recommended efficiency levels for 20-63 ton equipment. As noted above, the recommended EER is either 9.3 or 9.5 depending on whether a heat pump or gas-pak is included. This 0.2 differential is something new in 90.1-1999 that was not in previous standards and that is generally not used in incentive programs such as the CEE tier 2 program. We think the 0.2 adder for gas-paks is generous given our review of equipment on the market and we recommend that it not be included in the CEC standard unless manufacturers provide additional data and information supporting why this differential is needed.

Legislation establishing an EER 10 standard for this equipment was passed by the Maryland legislature in spring 2003 but vetoed by the governor, primarily due to concerns about ceiling fan standards in the same bill. In January 2004 the legislature overrode the Governor's veto and the Maryland standards are now law. The standards for very large air-cooled unitary air-conditioners take effect Jan. 1, 2006. Other states also have pending legislation including Connecticut, Maine, Massachusetts New Jersey, New York and Pennsylvania.

7. Recommendations

We recommend that the CEC adopt an EER 10 standard for these products, effective October 1, 2006. This standard would be fairly easy for manufacturers to meet as there are many existing products at this level and this level has been promoted for many years as part of CEE tier 2. In addition, since an EER 10.5 is clearly cost-effective, we recommend that a second efficiency tier at this level be adopted. However, since less groundwork has been laid for this level, several more years are needed. The industry is scheduled to phase-out most HCFC refrigerants in 2010 and will be redesigning many models to meet this schedule. We recommend that the CEC EER 10.5 level take effect Jan. 1, 2010, coincident with this refrigerant switchover.

Specifically, we recommend that the following standard be added to current California *Appliance Efficiency Regulations*, section 1605.3(c):

(3) ***Energy Efficiency Standards for Very Large Air-Cooled Unitary Air Conditioners.*** *The EER of air-cooled unitary air-conditioners manufactured on or after the effective dates shown, shall be not less than the applicable values shown in Table C-11.*

Table C-11
Standards for Very Large Air-Cooled Unitary Air Conditioners

Appliance	***Cooling Capacity (Btu/hr)***	***Minimum Standards***	
		Effective October 1, 2006	***Effective January 1, 2010***
Air-cooled unitary air conditioners	*240,000-760,000*	*10.0 EER*	*10.5 EER*

Note: These requirements apply to equipment with no heating source as well as equipment with electric resistance, natural gas, or propane heating. These requirements do not apply to heat pumps.

[Sections "(3)" and "(4)" should then be renumbered as "(4)" and "(5)".]

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